

## BROOKHAVEN NATIONAL LABORATORY

# ENVIRONMENT, SAFETY AND HEALTH STANDARD

RF AND MICROWAVES	2.3.2
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### I. INTRODUCTION

Radio frequency (RF) and microwave radiations are produced by a variety of industrial, scientific, and communication equipment. Such effects as hyperthermia, cataracts, lenticular opacitus, have been found in individuals subjected to chronic and acute exposures associated with the following activities: broadcasting, telecommunications, air and ship borne radar navigation, satellite communication, meteorology, metallurgy, food processing, sterilization, scientific research, and medicine. Additionally, there may be ancillary hazards associated with equipment used to generate these radiations. The purpose of this standard is to provide safety guidelines to minimize the potential hazards to health that radiofrequency and microwave generating equipment present to BNL employees and guests.

### II. SCOPE

This Standard shall apply to generating equipment operating in the portion of the electromagnetic spectrum, which extends from 30 KHz to 300 GHz. For guidance on frequency less than 30 KHz, contact a subject matter expert.

### III. RESPONSIBILITIES

- A. *Department Chairs/Division Managers* are responsible for ensuring implementation of this Standard.
- B. *Line Supervisors, Principal Investigators, or Process Owners* are responsible for the direct implementation of the provisions of this Standard and for ensuring compliance with all requirements listed in Section V. Specifically, supervisors shall
  - 1. Ensure that safe operating procedures pertaining to RF and microwave operations are established and executed.
  - 2. Provide adequate instructions in safety practices for all personnel who work with or near RF and microwave equipment, where any potential exposure could exceed levels listed in Table 1.
  - 3. Arrange with the ESH&Q Representatives to perform surveys initially and at regular intervals of RF and microwave sources, including areas within the scope of this Standard.
  - 4. Ensure that tests are made of all installed safety devices (interlocks, signals) initially and a least annually thereafter.
  - 5. Consult with ESH&Q Representatives before RF or microwave equipment is installed or modified. Maintenance or repair of established equipment is excepted.
  - 6. Supply ESH&Q Representatives and OMC with a list of personnel who work with or near RF and microwave equipment, where any potential exposure could exceed one-half the levels listed in Table 1.

- C. *Users* are responsible for complying with the provisions of this Standard.
- D. *Occupational Medicine Clinic* is responsible for assisting in implementing this Standard. Specifically, the Occupational Medicine Clinic shall
  - 1. Perform medical surveillance of listed personnel as stated in Section VII.
  - 2. Notify the employee's immediate supervisor and the ESH&Q Directorate whenever job-related irregularities are observed.
- E. The *ESH&Q Directorate* is responsible for assisting in implementing this Standard. Specifically, the ESH&Q Directorate shall
  - 1. Assist in establishing safety procedures pertaining to RF and microwave-producing equipment.
  - 2. Assist in providing adequate instructions in safety procedures to users who work with or may be exposed to RF and microwave radiation.
  - 3. Perform radiation surveys of RF and microwave installations, and maintain records of such surveys.
  - 4. Audit for compliance with this Standard.
  - 5. Maintain an inventory of all appropriate RF and microwave sources onsite.
  - 6. Work with Departments/Divisions to supply the Occupational Medicine Clinic with a list of all personnel who work with or near RF and microwave equipment, where any potential exposure could exceed one-half the levels listed in Table 1.

#### IV. HAZARDS

##### A. Thermal

Since the radiation in the frequency range of 30 KHz to 300 GHz is not energetic enough to produce ionization in living organisms, it is generally accepted that the principal effect of absorption of this energy is a rise in internal temperature.

Research directed toward revealing other possible deleterious effects is underway. Future editions of this Standard will reflect any new findings. Biological effects produced by microwaves are caused primarily by the heating of body tissue (hyperthermia). Organs lacking adequate blood supply for needed temperature regulation are the most susceptible. Biological effects are most pronounced in (1) abdominal organs (tissue damage), (2) eyes (cataracts), and (3) testicles (tissue damage).

##### B. Ancillary Hazard

Ancillary hazards arising from the generating equipment used to produce radiant energy at significant levels include

- 1. High voltage at lethal levels on components that are on or near the radiating elements.
- 2. Electric arcing to conducting surfaces from radiating elements at close range.
- 3. High-power RF induction heating units inducing high current in metal objects placed near the radiating element. Although the radiation itself may be harmless, the unexpected intense heat in the object could cause severe burns.
- 4. Radiation from RF and microwave equipment inducing energy in other apparatus, which can interfere with operations of associated circuits, including control circuits, bio-electronic implants (such as pacemakers), and ionizing radiation survey instruments.

## **V. RF AND MICROWAVE SAFETY MEASURES**

Equipment emitting RF and microwave radiations shall be operated in a manner such that exposure to operators and other personnel should be minimized. In no case shall exposure exceed the limits stated in Section VI. Three factors – time, distance, and shielding – can be used to minimize radiation hazards. RF and microwave radiation shall be subject to the following controls.

### **A. Administrative Controls**

1. Limit access to the radiation area to properly trained personnel. Signs and other visible and/or audible signals shall be used. The OSHA-approved warning symbol (Appendix 1), or ANSI warning symbols (IEEE C95.2 1999 Standard for Radio-frequency Energy and Current-Flow) for nonionizing radiation, shall identify all areas where potential exposures could exceed levels listed in Table 1.
2. Position devices with directional beams of radiation so that energy is harmlessly absorbed and not directed into any occupied area.
3. Include the hazards and possible consequences of overexposure to this radiation on posted safety instructions.
4. Supply operators in radiation areas (where built-in protection cannot be provided) with appropriate safeguards, such as goggles with gold film, microwave dosimeters, and portable shielding.
5. Examine personnel eyes before assignment to operations involving microwave equipment. Reexamine eyes annually. (See paragraph III-D).
6. Close visual examinations of energized microwave radiators and reflectors are not permitted.
7. Establish work permits and standard operating procedures to conduct operations in a manner that minimizes exposures. See ES&H Standard 1.3.5, Planning and Control of Experiments and ES&H Standard 1.3.6, Work Planning and Control for Operations. Address personnel exposure during maintenance operations in the work planning and control documentation.
8. Refer all personnel exceeding half the BNL Exposure Limits to the Occupational Medicine Clinic for medical evaluations.
9. Review the experiment/process annually and validate the assessment during ES&H Standard 1.3.5, Planning and Control of Experiments or ES&H Standard 1.3.6, Work Planning and Control for Operations reviews. If changes in the device/process occur that will result in increased exposures to RF or microwaves, or exposure to more personnel, then reassess the device.\*
10. Review tasks or operations that fall outside of the above envelope (e.g., routine operations that fall outside the 1.3.5 and 1.3.6 evaluations), such as work by technicians on RF sources that may be covered by SOPs or skill of the craft.\*
11. When conducting tours of areas, plan routes to minimize exposure to visitors.

\*Guidance: Examples of changes that may trigger re-evaluation include, but are not restricted to

1. Relocation of the device
2. Changing the power output of the device
3. Review of history of the device to determine if through equipment aging, the possibility of increased exposure may occur
4. Repair of equipment
5. Defects in housing or barriers
6. Changing interlocks
7. If the device has been damaged.

### **B. Design and Construction Criteria for Original Equipment**

1. Provide shielding and other control measures to minimize radiation leakage.
2. Guard exposed dummy loads to prevent burns.
3. Provide adequately sized electrical ground connections for RF and microwave equipment to harmlessly dissipate energy.
4. Eliminate sharp edges or points on equipment to avoid corona discharge.

5. Design RF and microwave heating equipment with adequate clearances around RF leads. Lengths of nonconducting cooling-water hose shall be provided where necessary.
6. Where possible, provide bypass capacitors on control power and instrument leads, which enter the RF compartment to control leakage without interfering with proper operation.
7. Design viewing ports to limit leakage radiation to acceptable levels, or shield them.

### **C. Engineering Controls**

1. Use barriers and interlocks to prevent operators and maintenance personnel from accidentally entering areas where radiation and ancillary hazards exist.
2. Whenever tests are done, replace radiating elements with dummy loads, where appropriate.
3. Consider area-monitoring equipment as a fixed part of the installation, wherever the potential for excessive radiation in occupied locations exists.
4. When possible, control the energizing switch for the equipment by a preset elapsed-time mechanism to limit the exposure period automatically.
5. See ESH Standard 1.5.1 Lockout/Tagout Requirements for further guidance.

## **VI. EXPOSURE LIMITS**

1. The BNL exposure limits, shown in Figure 1, are based on the latest American Conference of Governmental Industrial Hygienists (ACGIH) RF/microwave radiation protection standard for 30-kHz to 300-GHz frequency ranges of emissions. The levels that should not be exceeded at BNL are shown in Table 1, Part A and Part B. The standard varies depending on the frequency of concern. These limits apply to both whole-body and partial-body irradiation.
2. Regulations of the DHHS Food and Drug Administration, Bureau of Radiological Health governing microwave oven leakage, provide for a limit of  $1 \text{ mW/cm}^2$  measured the same way throughout the useful life of the unit.

## **VII. MEDICAL SURVEILLANCE**

There are several areas of the body that are subject to the deleterious effects of microwaves. The most susceptible is the lens of the eye. Studies using experimental animals have shown that given enough radiation at certain frequencies, a cataract can be induced. The first physical signs of this are lenticular opacities and vacuoles. The Occupational Medicine Clinic shall annually examine the eyes of those potentially exposed to RF or microwaves more than half the applicable standard in their work assignments. When there are indications of job-related irregularities, the employee's supervisor and the ESH&Q Directorate shall be notified.

**TABLE 1. Radiofrequency/Microwave Threshold Limit Values**  
**Part A: Electromagnetic Fields<sup>A</sup> (f=frequency in MHz)**

Frequency	Power Density (s) E-Field, H-Field (mW/cm <sup>2</sup> )	Electric Field Strength Squared (V/m)	Magnetic Field Strength Squared (A/m)	Averaging Time E2, H2 or S (minutes)
<b>30 kHz to 100 kHz</b>	(100, 1,000,000)□	614	163	6
<b>100 kHz-3 MHz</b>	(100, 10,000/f <sup>2</sup> )□	614	16.3/f	6
<b>3 MHz to 30 MHz</b>	(900/f <sup>2</sup> , 10,000/f) □	1842/f	16.3/f	6
<b>30 MHz to 100 MHz</b>	(1.0, 10,000/f <sup>2</sup> )⊥	61.4	16.3/f	6
<b>100 MHz to 300 MHz</b>	1	61.47	0.163	6
<b>300 MHz to 3 GHz</b>	f/300			6
<b>3 GHz to 15 GHz</b>	10			6
<b>15 GHz to 300 GHz</b>	10			616,000/f <sup>1.2</sup>

\*f=frequency in MHz    <sup>A</sup> The exposure values in terms of electric and magnetic field strengths are obtained by spatially averaging over an area equivalent to the verticle cross section of the body (projected area.)

⊥ These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with exposure limits at higher frequencies and are displayed on some instruments in use.

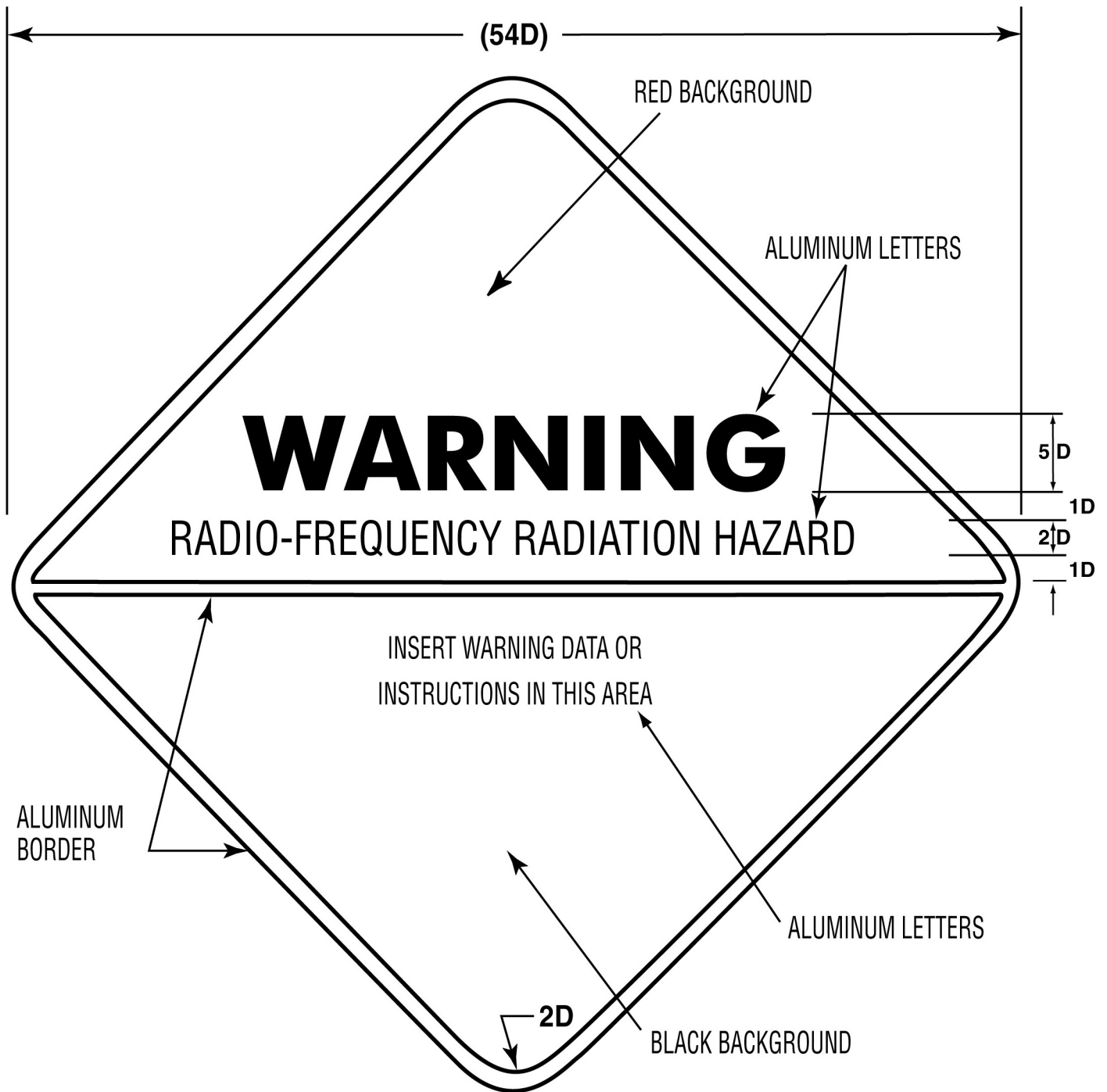
**Part-B: Induced and contact Radiofrequency Currents<sup>1</sup>**  
**Maximum Current (mA)**

Frequency	Through Both Feet	Through Each Foot	Contact	Averaging Time
<b>30 kHz to 100 kHz</b>	2000f	1000f	1000f	1 second <sup>C</sup>
<b>100 kHz to 100 MHz</b>	200	100	100	6 minutes <sup>D</sup>

<sup>1</sup> The current limits given may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object. See TLV text for additional comments.

<sup>C</sup> I is averaged over any 1-second period

<sup>D</sup> I<sup>2</sup> is averaged over a 6-minute period (e.g., for either foot or hand contact, I<sup>2</sup> ≤ 60,00 mA<sup>2</sup>-minutes subject to a ceiling limit of 500 mA).



1. Place handling and mounting instructions on reverse side.
2. D = Scaling unit.
3. Lettering: Ratio of letter height to thickness of letter lines.
  - Upper triangle : 5 to 1 Large
  - 6 to 1 Medium
  - Lower triangle 4 to 1 Small
  - 6 to 1 Medium
4. Symbol is square, triangles are right-angle isosceles.

## Appendix 1. OSHA Radio-Frequency Radiation Hazard Warning Symbol

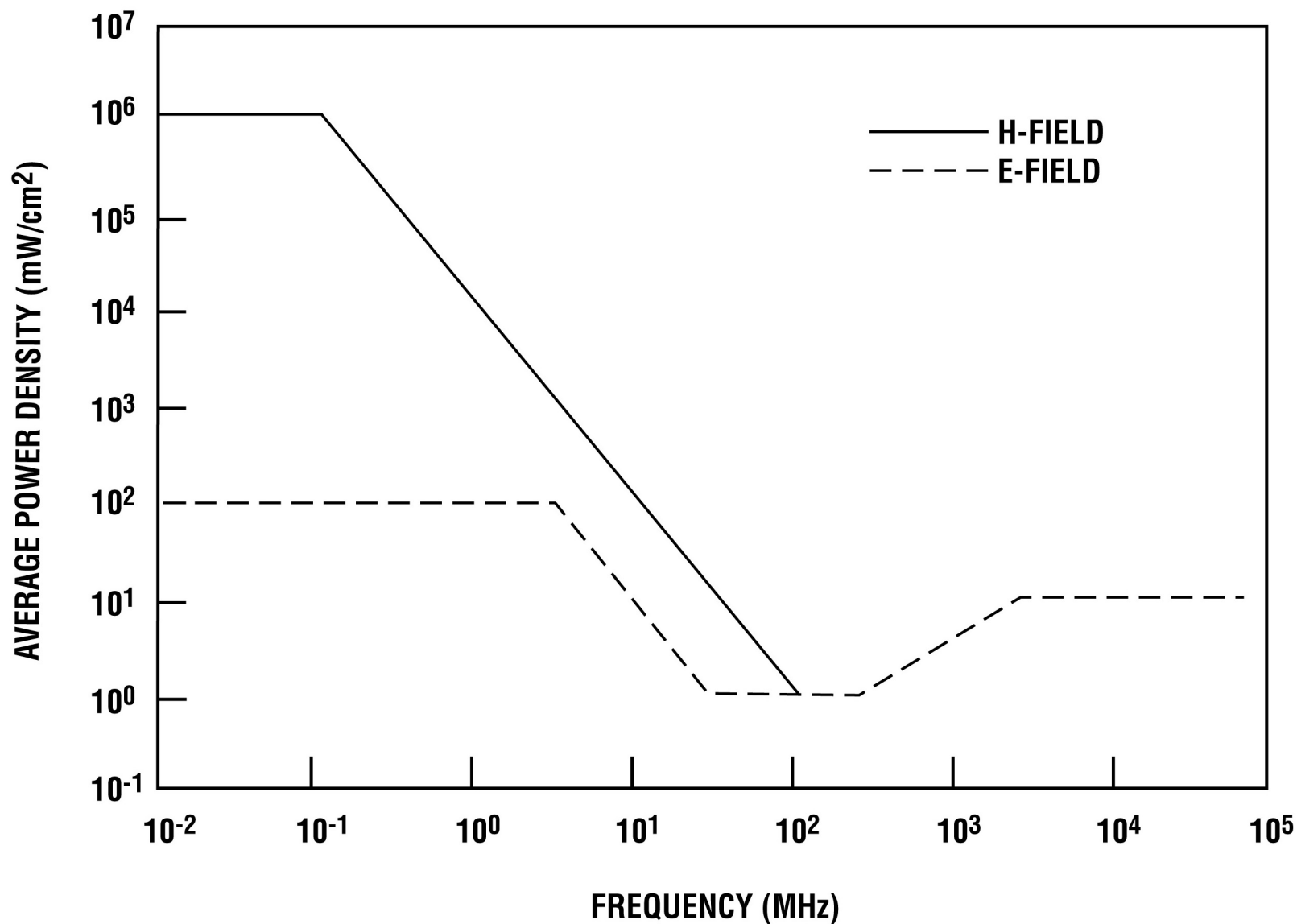


Figure 1. Threshold limit (TLV) for Radiofrequency/Microwave Radiation in the Workplace (whole-body specific absorption rate [SAR] <0.4 W/kg).